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## DETAILED DESCRIPTION

## [Detailed Description of the Invention]

[0001]

[Industrial Application] This invention relates to the manufacture method of the semiconductor device in which the low good gate insulator layer and silicon-carbide interface of interface level density were formed, in a semiconductor device, a semiconductor integrated circuit, etc. which carried the metal-oxide-film-semiconductor (MOS) structure where the silicon carbide was used as a semiconductor, or the MOS electric field effect type transistor.

[0002]

[Description of the Prior Art] The interface level density generated in the gate insulator layer / silicon-carbide interface which is a wide gap semiconductor, and which was formed on the silicon-carbide substrate (SiC substrate) is high 1 or more figures, and has become one of the causes of low channel mobility from the interface level density which generates a silicon substrate in the gate oxide film / silicon interface which oxidized thermally and was formed.

[0003] Moreover, it is with the MOS capacitor usually produced using the silicon substrate. Although the interface level density generated in a gate oxide film / silicon interface by carrying out hydrogen annealing at 400 degrees C, and carrying out termination of the dangling bond is reduced and it is made form a good interface, even if it carries out annealing at 400 degrees C with the MOS capacitor produced using the silicon-carbide substrate, there is no conspicuous effect which reduces the interface level density generated in a gate insulator layer / silicon-carbide interface.

[0004]

[Problem(s) to be Solved by the Invention] Then, termination of the uncombined bond of the silicon or carbon followed and kicked to the MOS capacitor interface produced using the silicon-carbide substrate in this invention is carried out, and it aims at forming a good interface with low interface level density.

[0005] In order to solve the above technical problem, invention-in-this-application persons found out wholeheartedly that the MOS capacitor of interface level density was obtained by annealing the MOS capacitor produced using the silicon-carbide substrate in the atmosphere containing the hydrogen under an elevated temperature as a result of research.

[0006]

[Means for Solving the Problem] This invention proposes the manufacture method of a semiconductor device of annealing in the atmosphere which contained hydrogen in 600-1600 degrees C, after forming more than two-layer (of an oxide film and/ or a nitride / one layer or two-layer) as a gate insulator layer on the semiconductor substrate which has a silicon carbide in the best layer at least based on the above-mentioned knowledge.

[0007] In addition, although there are very many polytypes, such as 3 C-SiC, 4 H-SiC, 6 H-SiC, and 15 R-SiC, in a silicon carbide (SiC), as long as the silicon carbide used as a semiconductor substrate in this invention is SiC, the thing of which type is sufficient as it.

[0008] Moreover, as long as the best layer is SiC, the structure which has 3 C-SiC on Si, and the structure which has 3 C-SiC on 6 H-SiC or 4 H-SiC are sufficient as the structure of a semiconductor substrate.

[0009] As an oxide film or a nitride, although a silicon oxide or a silicon nitride is common, which oxide film or nitrides, such as an aluminum oxide film, a tantalum-oxide film, an aluminum nitride film produced on another conditions, and a gallium nitride, are sufficient, without being limited to this.

[0010] As a method of carrying out the laminating of the oxide film on a silicon-carbide substrate, although an oxide film may be formed by the forming-membranes method on a silicon-carbide substrate, a silicon-carbide substrate may be oxidized thermally and an oxide film may be formed.

[0011] When forming a silicon oxide on a silicon-carbide substrate by the forming-membranes method, for example, after forming silicon on a silicon-carbide substrate by the MBE method (the Molecular beam epitaxy method) or CVD (chemistry gaseous-phase method), you may oxidize thermally and form a silicon oxide may be formed by CVD and the SOG method (the spin on glass method).

[0012] On the other hand, as a method of carrying out the laminating of the nitride, the LPCVD method (low voltage chemistry gaseous-phase method) and plasma nitriding are employable on a silicon-carbide substrate.

[0013]

[Function] That is, after forming the gate insulator layer which consists of an oxide film or a nitride on a silicon-carbide (SiC) substrate, by annealing in the atmosphere containing 600 degrees C - 1600 degrees C hydrogen, termination of the dangling bond of the silicon which exists in an insulator layer / silicon-carbide interface, or carbon can be carried out, it can reduce interface

level density, and can form a good interface.

[0014] Since the melting point of the silicon oxide which the termination of the dangling bond of the silicon which exists in a gate insulator layer / silicon-carbide interface, or carbon is not fully made, and is used as for example, a gate insulator layer was 1600 degrees C when annealing below 600 degrees C, the annealing temperature was made into the range of 600 degrees C - 1600 degrees C.

[0015] Moreover, the hydrogen pressure force in the case of hydrogen annealing is at 0.1Pa or less, since there is no effect it is too low and a dangling bond carries out [ an effect ] termination, and the hydrogen pressure force returned oxygen from the silicon oxide which the hydrogen pressure force is too high in the hydrogen pressure force being more than an ordinary pressure (1.01x10<sup>5</sup>Pa) again, for example, is used as a gate insulator layer, reduced the membranous quality of an oxide film and caused the fall of a dielectric breakdown voltage, the hydrogen pressure force was made into the range of 0.1Pa - 1.01x10<sup>5</sup>Pa.

[0016] Moreover, hydrogen annealing by this invention can be performed in mixed-gas atmosphere with inert gas, such as the others, hydrogen and inert gas in hydrogen gas especially nitrogen, an argon, and helium.

[0017] In this case, hydrogen concentration is too low in the pressure of gas atmosphere being fixed to an ordinary pressure (1.01x10<sup>5</sup>Pa), and the hydrogen concentration (hydrogen flow rate/(hydrogen flow rate + inert gas flow rate)) in mixed gas being below 0.5 %, and a dangling bond carries out termination -- it is ineffective and hydrogen concentration was made into 0.5% - 100% of range.

[0018] Furthermore, since annealing time was too short in hydrogen annealing time being 10 or less seconds, and could not fully carry out the termination of the dangling bond, and the oxygen of the silicon oxide too long [ in annealing time being 3 hours or more / annealing ] and used as a gate insulator layer was returned, the membranous quality of an oxide film deteriorated and the fall of a dielectric breakdown voltage was caused, annealing time was made into the range of 10 seconds - 3 hours.

[0019]

[Example] Hereafter, the example of this invention is shown.

The sacrifice oxide film was formed after the usual RCA washing, and the 18 degree OFF 4 H-SiC EPI substrate (0001) (Si side, n type, Nd-Na=1x10<sup>16</sup>/cm<sup>3</sup>) of examples was removed by HF. Subsequently, after forming a 36nm - 50nm oxide film by dry oxidation at 1100 degrees C, it quenched from 1100 degrees C to the room temperature. Then, temperature was changed to 400 degrees C - 1000 degrees C, and hydrogen annealing was performed for 30 minutes. The hydrogen pressure force was 5.6x10<sup>3</sup>Pa at 1000 degrees C. Finally aluminum was used for the gate electrode and the ohmic contact, and the MOS capacitor was produced.

[0020] It is hydrogen annealing in the RF (f= 100kHz) valve flow coefficient property which drawing 1 is the cross section showing typically the MOS capacitor obtained in the example 1, and measured drawing 2 using this MOS capacitor.

[0021] valve flow coefficient and IV property are measured on condition that darkness in the box of the shielded metal, and the dashed line of the left-hand side in drawing 2 is an ideal curve calculated from the oxide-film capacity of 25V, and Nd-Na=1x10<sup>16</sup>/cm<sup>3</sup>. A right-hand side dashed line is a valve flow coefficient characteristic curve when not carrying out hydrogen annealing, and the solid line inserted with the right-hand side dashed line and the left-hand side dashed line is a valve flow coefficient characteristic curve at the time of carrying out hydrogen annealing from right-hand side, respectively at 400 degrees C, 500 degrees C, 600 degrees C, 700 degrees C, and 1000 degrees C.

[0022] Among drawing, the thing with the actually measured value lower than the calculated value when a gate voltage is lower than -5V has very few minority carriers generated at a room temperature for the wide gap of 4 H-SiC, and is because it will not be in equilibrium.

[0023] moreover, valve flow coefficient characteristic curve (right-hand side dashed line) when not carrying out hydrogen annealing -- setting -- a flat-band-voltage shift -- 15.7V -- very much -- large -- going and return of a gate voltage -- about 1 -- the hysteresis of V is shown and this means that there is very much interface level density.

[0024] In valve flow coefficient characteristic curve of the solid line inserted with the right-hand side dashed line and the left-hand side dashed line, although a flat-band-voltage shift decreases when hydrogen annealing is carried out at 400 degrees C - 500 degrees C, since the value is large and a hysteresis is also large, it cannot still be used in fact.

[0025] On the other hand, when hydrogen annealing is carried out at 600 degrees C, a hysteresis disappears; mostly, and when it is in the state where it can actually be used and hydrogen annealing is carried out at 1000 degrees C, a hysteresis disappears and approaches an ideal curve.

[0026] In addition, although a hysteresis disappearing completely and approaching an ideal curve further was expected when hydrogen annealing was carried out above 1000 degrees C, since the melting point of the silicon oxide currently generally used as a gate insulator layer was 1600 degrees C, the range of an annealing temperature was made into 600 degrees C - 1600 degrees C.

[0027]

[Effect of the Invention] Above, in short, according to this invention, interface level density can fully be reduced and good insulator layer / silicon-carbide interface which is fully equal to actual use can be acquired by carrying out termination of the silicon which exists in a gate insulator layer / silicon-carbide interface, or the carbonaceous tangling bond from hydrogen.

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